



Designation: C1722 – 23

Standard Guide for Repair and Restoration of Dimension Stone¹

This standard is issued under the fixed designation C1722; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide describes materials and procedures for restoring facades constructed of or finished with dimension stone. All of the materials, procedures, and principles are suitable for restoration of historic and nonhistoric structures.

1.2 This guide is not intended to address restoration of interior dimension stone, although many of the materials and procedures may be suitable for interior use.

1.3 *Units*—The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 ASTM Standards:²

- C5 Specification for Quicklime for Structural Purposes
- C10 Specification for Natural Cement
- C91 Specification for Masonry Cement
- C119 Terminology Relating to Dimension Stone
- C141 Specification for Hydrated Hydraulic Lime for Structural Purposes
- C150 Specification for Portland Cement

¹ This guide is under the jurisdiction of ASTM Committee C18 on Dimension Stone and is the direct responsibility of Subcommittee C18.07 on Environmental Properties, Behavior, and Cleaning.

Current edition approved March 1, 2023. Published April 2023. Originally approved in 2011. Last previous edition approved in 2018 as C1722 – 18. DOI: 10.1520/C1722-23.

² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

- C207 Specification for Hydrated Lime for Masonry Purposes
- C270 Specification for Mortar for Unit Masonry
- C1180 Terminology of Mortar and Grout for Unit Masonry
- C1242 Guide for Selection, Design, and Installation of Dimension Stone Attachment Systems
- C1324 Test Method for Examination and Analysis of Hardened Masonry Mortar
- C1489 Specification for Lime Putty for Structural Purposes
- C1515 Guide for Cleaning of Exterior Dimension Stone, Vertical And Horizontal Surfaces, New or Existing
- C1521 Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints
- C1707 Specification for Pozzolanic Hydraulic Lime for Structural Purposes
- 2.2 OSHA Directive:³
- STD 1-12.026 Abrasive Operations Using Cut Off Wheels and Masonry Saws

3. Terminology

3.1 *Definitions*—For definitions of terms used in this guide, other than those listed below, refer to Terminology C119 and Terminology C1180.

3.2 Definitions of Terms Specific to This Standard:

3.2.1 *defect, n*—naturally occurring flaw in the stone.

3.2.2 *dimension stone restoration consultant, n*—one who is knowledgeable and experienced with the care, restoration, and repair of building dimension stone.

3.2.3 *distress, n*—localized damage of stone units such as cracks, chips, holes, deterioration, bowing, and projections that have been broken off or worn down caused by wear, erosion, settlement, displacement, or other adverse chemical or mechanical actions.

3.2.4 *dutchman repair, n*—a stone repair method whereby a portion of a stone unit is cut out and replaced with another piece of stone (called a dutchman). The dutchman is usually rectangular or square in shape, but may also be rounded, and is usually at a corner or edge of the stone unit.

3.2.5 *pointing, v*—placing mortar in the outer portion of the joints between stone units. To point stone joints, the outer

³ Available from Occupational Safety and Health Administration (OSHA), 200 Constitution Ave., NW, Washington, DC 20210, <http://www.osha.gov>.

portion of the joints must either be left open during installation or cut or ground out, that is, have the mortar removed from the outer portion of the joint. New mortar is then pressed into the joint with a pointing tool. The increased compaction of the new mortar provides an improved resistance to water penetration at the joint compared to the primary stone setting mortar.

3.2.5.1 *repointing, v*—the removal of existing mortar from the outer portion of the joints between stone units and the subsequent pointing of the joints.

3.2.5.2 *tuck pointing (tuckpointing, tuck-pointing), v*—this term is intentionally not used in this standard, because it is often used inconsistently. It is variously used to mean repointing, simply pointing, or applying a raised bead of mortar (often of a different color) down the middle of mortar joints.

3.2.6 *proprietary repair mortar, n*—an exclusively manufactured product formulated from cementitious compounds, fine aggregates, mineral pigments, possibly bonding agents, and other additives. It is used for filling cracks, holes, and other depressions in stone units or for rebuilding the surface of damaged stone units to their original profile.

3.2.7 *repair mortar, cement-based, n*—repair mortar utilizing portland cement, masonry cement, blended cement, mortar cement, or natural cement as the primary binder.

3.2.7.1 *repair mortar, polymer-modified, n*—cement-based repair mortar incorporating a dry or liquid polymer modifier as a secondary binder, to alter the performance properties

3.2.7.2 *repair mortar, polymer-based, n*—repair mortar consisting of a polymer binder and aggregates, without cement or hydraulic components.

4. Significance and Use

4.1 The purpose of this guide is to assist those who wish to restore facades constructed of or finished with dimension stone. It is an aid to owners, building managers, architects, engineers, contractors and others involved with restoring dimension stone.

4.2 This guide is not meant to supersede manufacturers' directions and recommendations for the use of their specific products, or written directions from the architect or building owner. When manufacturers' directions are in conflict with this guide, follow their recommendations or consult with their technical staff for further direction.

4.3 Prior to undertaking a full-scale repair or cleaning procedure, the methods under consideration for repair, patching or cleaning should be tested on an area not easily visible or on sample stones. The test will assist in judging the effectiveness of the chosen method and permit assessment of potential damage to the building stone. Completely evaluate the success of the sample repairs before undertaking the full-scale cleaning or repair procedure.

5. Condition Survey and Restoration Plan

5.1 The first step in a restoration project is to conduct a project survey consisting of a review of existing original architectural drawings and specifications and any original stone shop drawings that may be available. The stone shop drawings

contain detailed information on stone and anchoring that is not always found in the architectural drawings. The shop drawing review is followed by a thorough examination of all exposed stone surfaces and related elements of the building envelope. Document distressed areas and existing repairs. Determine the causes of observed distress to avoid performing cosmetic repairs while failing to correct the underlying problems. As an example, if problems result from water damage, the source of water penetration must be found and corrected if the repairs are to be successful and long lasting. If the damage to the stone is a result of structural instability, that structural issue must be addressed before repairs are made.

5.1.1 A dimension stone restoration consultant experienced in natural stone facade design and construction should participate in the condition survey. If structural distress is observed, consult with a qualified engineer with stone facade design experience. For stone displaying deterioration with an unknown cause, a petrographer specializing in dimension stone analysis can be consulted to determine whether a failure is related to inherent properties or mineralogical composition of the stone.

5.1.2 During the condition survey, identify and document repairs performed during previous restorations. The condition of existing repairs should be assessed to determine if they are stable, if they have failed, if they are a potential threat to the building fabric, or if they are posing a safety risk. Existing repairs can be made more apparent or can be damaged by cleaning or other restoration processes. The restoration consultant will be able to help with the proper procedures concerning previous repairs.

5.1.3 When necessary, appropriate field or laboratory testing, or both, is normally included with the condition survey to verify the nature of existing materials and the extent of the work needed to restore the project to the desired condition. Cleaning compounds and repair materials under consideration should be evaluated and tested to confirm that they will be effective and will perform without detrimental effects to the stone for the life of the building.

5.2 Once the condition survey is complete, prepare a restoration plan describing the repair and restoration work to be done. Perform the repairs and cleaning in a systematic, sequential order that will avoid damage to previously completed phases of the project.

5.2.1 Structural repairs must precede cosmetic repairs. For example, if expansion from rusting anchors is causing the stone to crack, the anchors must be replaced or treated before repairing cracks.

5.2.2 Perform testing of existing materials sufficiently in advance of restoration work to allow suitable cleaning, patching, repair, and replacement materials to be identified.

5.2.3 When chemical cleaners are used, perform the cleaning before the patching. Some cleaning compounds adversely affect the color and strength of the installed patch. Performing the cleaning first will help prevent damage or discoloration of the patching materials and will also allow the patch materials to be matched to the cleaned surfaces of the original material.

5.2.4 If mortar in the joints is missing or deteriorated to the extent that water intrusion will occur, the joints must be

repointed and allowed to cure before using a wet cleaning method. This is especially important if a water soak preparation or pressure water spray cleaning method is specified.

5.2.5 Water repellents and clear sealers are sometimes inappropriately applied to limit water entry into stone. The application of a sealer will reduce the ability of the water that does enter the stone (from the bottom or back side) to evaporate from the exposed surfaces. Limiting evaporation can damage completed stone patches, accelerate surface loss in the form of chips, or cause exfoliation due to freezing of trapped water or accumulation of water-borne crystalline minerals within the body of the stone. Also, the patch material is likely to absorb the sealer at a different rate than the stone, which could make the patches more noticeable. Consult the sealer or water repellent manufacturer before the application to any stone to be sure the correct product is being used for a correct resolution of the problem.

5.3 The National Historic Preservation Act allows qualifying historically significant buildings or structures to be restored using federal funds set aside for historic preservation. The permitted type and extent of restoration work may be limited by government regulations. A formalized Historic Structures Report is used in these cases to outline the property's history, existing condition, goals for the use of the property, and provides a recommended treatment approach and scope of work for restoration. The Historic Structures Report is a multidisciplinary task and a team of several consultants consisting of historians, architects, engineers, materials scientists, and conservators is usually required to complete the report.

6. Stone Patching

6.1 *Patching, General*—Patching small areas of distress is commonly performed in order to avoid replacing full stone units. This may be preferable in certain situations to preserve as much of the historic fabric of the structure as possible. However, areas of distress that do not impact the overall integrity of the stone unit and will not lead to further degradation of the stone, or do not detract significantly from the stone's appearance, are often left untreated.

6.1.1 Patching compounds must properly adhere to and match the stone as closely as possible, not only in appearance, but also in physical properties. Patching materials must be compatible with original stone.

6.1.2 The original stone may be repaired with a patch, in lieu of replacement, because of historic value, a lack of availability, or difficulty replacing whole pieces. For these reasons, it is very important that the original stone being repaired be carefully protected from further damage. The physical properties of patching compounds should be verified so the resulting performance characteristics of the patch do not conflict with the performance characteristics of the surrounding stone. It is generally agreed that it is better for the patch (which can be easily replaced) to fail than to cause any further damage to the existing, historically valuable, irreplaceable, facade. In the following paragraphs, there are specific examples of physical properties and how they affect the viability of the patch with a specific stone.

6.1.3 The combined compressive strength and modulus of elasticity of the patching material should produce similar or lower performance characteristics to the analogous properties of the original stone for a non structural repair. Consult an experienced stone restoration consultant to confirm that the combined properties of the patching material do not result in performance characteristics that could damage the particular stone for a specific project.

6.1.4 Patching compounds should also have a comparable coefficient of thermal expansion to that of the stone being patched. This is desirable so that the differential thermal expansion will not stress the patch and cause a loss of bond.

6.1.5 Water absorption and water vapor transmission characteristics of the stone must be considered when selecting a patching compound. This is especially important when patching an absorptive stone. If the patch does not transmit water vapor at a similar rate as the surrounding stone, it may trap moisture and dissolved salts behind it, which can cause the patch to lose bond or deteriorate. This can also cause deterioration of the surrounding stone. Polymeric bonding agents, such as high solids epoxy, may also inhibit water vapor transmission. These are generally not recommended and should only be used if they can demonstrate proper water vapor transmission by testing or exemplars.

6.1.5.1 A patch, whether cementitious or polymer-based, will normally be more obvious after wetting by rain or during cleaning. This phenomenon occurs with most patching materials and is not necessarily a sign of badly matched properties. Patching material is designed to match dry stone. Once the wetted stone returns to the dry condition, a properly installed patch will return to its original state, matching the surrounding stone.

6.1.6 Ground stone, crushed stone, or stone dust of the same variety as the stone being patched is sometimes added to the patching compound to help match the patching material properties to the stone properties. Mixing these additional materials into the patching compound can cause the patch to lose strength, lose bond, or cause difficulty in finishing. Therefore, adding material to a manufacturer's patching compound is generally not recommended but sometimes cannot be avoided. For example, it is sometimes necessary to use ground or crushed stone added topically to replicate finishes such as exposed aggregates, granite crystals, contrasting colored crystals, etc. When a patch is deep, the manufacturer sometimes recommends adding matching stone aggregate to prevent excessive shrinkage. When necessary, additional materials should only be added under the guidance of the manufacturer of the patching compound.

6.2 *Cementitious Repair Mortars*—Repair mortars are generally suitable for patching unpolished stones and are especially suitable for porous stones. Simple job site mixes of portland cement, sand, and pigments have been used but are inconsistent and often fail within a short time. Proprietary repair mortars often contain polymeric additives to improve bonding and increase flexibility. Suppliers of proprietary repair mortars should provide manufacturers' data to show that the physical properties and the rate of the water vapor transmission for their product are similar to the stone being repaired.

Proprietary repair mortars that are custom blended to match the color and texture of the original stone are available. For stone that exhibits a range of colors, repair mortar will generally have to be prepared at the site by mixing two or more of the manufacturer's standard or custom colors, allowing the proper color to be achieved without changing the properties or the bond of the repair mortar.

6.2.1 *Patching Stone with Repair Mortars*—The following guidelines represent accepted industry procedures for patching using cementitious repair mortars. These guidelines will assist the installer and specifier in planning the repair and selecting the proper mortar for their particular need. Every manufacturer should provide directions for the proper use of their mortar. Users should understand and follow the manufacturer's written directions.

6.2.1.1 *Preparation*—Remove deteriorated and loose material from area to be patched to uncover solid, sound stone. Remove additional material to sufficient depth, especially at edges of area to be patched, so that patch will be at least ½ in. (12 mm) thick but not less than that recommended by mortar manufacturer. Some repair mortar manufacturers recommend ¼ in. (6 mm) minimum thickness. Prepared area is to have square edges. In some cases, undercut edges are specified to improve mechanical bond, but the resulting thin, tapered edge increases the risk of damage at the edge of the final patch. If the patch abuts the edges of an adjacent stone unit, provide forms to shape the perimeter of the patch and prevent it from bridging mortar or sealant joints. Alternatively, cut the extra material out of the joint after curing per manufacturer's directions.

6.2.1.2 After unsound material removal and edge preparation are completed, clean the entire area with potable water and a bristle brush to remove dust and loose material. Rinse the area to be patched, allowing the adjacent stone to remain damp. The bond of the patching material to the stone is directly affected by the moisture content of the stone being patched. The amount of water in the stone affects the absorption of the bonding agents into the original sound stone. If the stone is wetted incorrectly (too dry or too wet) the bond will be adversely affected. Manufacturers' directions vary regarding the amount of water that should be on the stone when applying the patching mortar. Be sure to completely understand and follow manufacturers' recommendations for wetting stone prior to applying patching material.

6.2.1.3 Generally, larger patches and patches on the underside of projecting courses require the use of threaded rods to hold the patching material in place. The threaded rods must be made of a corrosion-resistant metal, typically type 304 or 316 or stainless steel. The threaded rods must be securely fixed to the existing stone. Usually this is done by epoxying the pins in holes drilled into the sound stone. The epoxy manufacturer will recommend the proper size hole for the diameter dowel being used. Good practice dictates that the threaded rods be installed in tandem at opposing angles to create a mechanical bond with the patching material. Stainless steel helical anchors are also used for this purpose. Nylon pins are not acceptable because they shear easily, have unfavorable thermal expansion characteristics, and do not hold their shape over long periods of

time. Consult a stone restoration consultant on the proper application of threaded rods.

6.2.1.4 *Bond Coat*—Before applying the main patch material, apply a thin, specially mixed coat of repair mortar to the patch area per the manufacturer's recommendations. This bond coat is mixed to a thinner consistency than the final repair material. The actual consistency varies a great deal between the different manufacturers. Apply the bond coat to wetted stone and work material into crevices and depressions, maximizing its contact with the stone. Always review the manufacturer's directions for proper bond coat consistency and application.

6.2.1.5 *Application*—Apply repair mortar while bond coat is still wet. Apply the mortar in one or more layers of thickness as recommended by mortar manufacturer, but not less than ¼ in. (6 mm) nor more than recommended by mortar manufacturer. Roughen the surface of layers that are to receive another layer. Forms are used to keep patch material out of the joints. If the repair mortar gets into joint space, scrape the repair mortar out of the joint while it is still pliable or cut the mortar out of the joint after it is fully cured. Do not leave repair mortar in the joint space.

6.2.1.6 *Temperature*—Only apply the repair mortar in the temperature ranges recommended by the repair mortar manufacturer (typically between 40 and 90 °F, 5 and 32 °C). Cold temperatures can freeze the repair mortar or inhibit its cure. Temperature above 90 °F, low humidity, high wind, direct sunlight, or a combination of these factors will cause the mortar to dry too fast, causing color changes, excessive shrinkage and cracking, and weakening of the patch. Colored repair mortars may exhibit color differences when cured at a lower temperature range.

6.2.1.7 *Finishing*—Work should be performed by skilled craftsmen using methods recommended by the repair mortar manufacturer. An evaluation sample should be prepared for the particular stone being patched. The sample patch should be approved before full-scale work is undertaken. Trowel, scrape, tool, or carve surface of patch to match surface of surrounding stone. Make samples using different finishing methods to see which works best for the particular stone being patched. Samples applied to the actual masonry should be approved before beginning work. Test samples applied to plywood or other materials different than the original may affect the final color of the mortar. Sometimes, during application, the patching material gets on the surrounding stone. The residual patch material must be cleaned off the face of the surrounding stone with clean water and a sponge as soon as possible. If the residual patch material is allowed to cure, it will cause a permanent discoloration of the stone.

6.3 *Polymer-Based Materials*—Polymer-based patching materials typically possess excellent adhesion and flexibility but may deteriorate from exposure to sunlight or exterior use. Polymer-based patching materials are most suitable for use with polished stone, since they can be finished to a similar gloss. Available materials are generally either a polyester or an epoxy. Epoxies may tend to chalk or yellow on exposure to sunlight. The appearance and some physical properties of epoxy patching materials can be made to better match that of the stone being patched by mixing them with ground or

crushed stone of the same variety. (See 6.1.3 for additional information on the use of fillers.) Even though products containing polyester resins are marketed for use on stone, polyester resins possess poor thermal compatibility and very low water vapor transmission compared with stone. This, when combined with a high level of brittleness, makes polyester resin-based materials poorly suited for exterior stone repairs.

6.3.1 *Patching with Polymer-based Materials*—The guidelines below are to illustrate general proper procedures for patching stone using polymer-based materials. These guidelines will assist the installer and specifier in planning the repair and selecting the proper polymer-based materials for their particular need. Every manufacturer provides directions for the proper use of their material. Users should understand and follow the manufacturer’s written directions.

6.3.1.1 *Preparation*—Remove deteriorated and loose material from the original stone to be repaired until solid, sound stone remains. Remove enough additional material to sufficient depth, especially at edges of area to be patched, to allow a patch that will be at least $\frac{1}{8}$ in. (3 mm) thick with square edges. If the patch abuts the edges of a stone unit, forms must be provided to shape perimeter of patch and to prevent the patch from bridging a mortar or sealant joint. Clean the prepared area with compressed air or water and a bristle brush to remove dust and loose material; remove oils, paints, and other materials that might interfere with bond. If water or solvents are used, allow the stone to dry thoroughly before applying patching material.

6.3.1.2 *Application*—Apply a thin coat (as defined in manufacturers’ recommendations) of polymer-based material to the area to be patched. Work the material into crevices and depressions. Apply polymer-based patching material in one or more layers $\frac{1}{8}$ in. (3 mm) or more in thickness but not exceeding manufacturer’s recommendations; allow each layer to cure before applying the next layer as recommended by manufacturer. Slightly over-fill patched area to allow for finishing.

6.3.1.3 *Finishing*—After the patch has cured, remove the excess material and finish to match surrounding stone. For large patches, use stone finishing tools and methods used in fabrication shops. For small patches in honed-finished stone, finish with fine sandpaper used with a hard sanding block. For small patches in polished-finish stone, finish by fine sanding using a hard sanding block, then successively finer sanding using a soft backing followed by buffing with a hard felt pad with polishing compound.

7. Whole Stone Replacement

7.1 The choice of repair or replacement for any building is often dictated by the condition of the stone and its location on the building. If the historic stone facade is in good overall condition, but just a few stone units are severely deteriorated, replacement of those few stones could be appropriate. Stone replacement does become necessary when a majority of the stone on the building is deteriorated or damaged. The deterioration can be from many issues including, efflorescence, previous chemical cleaning, or a harsh climate. Malleable iron or carbon steel stone anchors that have corroded can also cause damage to stone on a building. If a large enough quantity of the

stone is deteriorated, it becomes more feasible to replace the stone with new stone of the same type. Stone replacement in kind is often avoided for historic restoration because new stone simply does not match the weathered patina of the existing stone. Usually a stone restoration consultant will try to save or stabilize the existing stone because the wear, deterioration, and cracks have historical significance. Also, removal of an existing stone could damage surrounding stone. If the existing stone is deteriorated to the point that it is structurally unsound, the best option then is to replace the damaged stones. However, stone replacement in kind is often used to repair non-historic stone facades when matching replacement stone is readily available and the damaged stones are easily removed.

7.1.1 When stone replacement is used for restoration of historic facades, every effort should be made to use replacement stone that is as similar as possible to the original stone. For minor replacement, stone salvaged from an inner wythe of the wall may be available for reuse on the exposed surface. Similarly, stone may be salvaged from new wall openings made necessary by functional adaptations of the building. Another technique that is similar to replacement involves removing a stone unit and replacing it in its original position after refinishing and possibly reversing it. Unfortunately, these replacement stone sources may be less practical than they seem due to the difficulties in removing the stone without causing substantial damage.

7.1.2 Recommendations for the removal process, stone bracing, and design of replacement anchors should be specified by a qualified stone engineer. In mortar-set building facades, removal of damaged stone for replacement may result in adverse consequences that are not obvious. Replace one stone at a time letting the setting mortar harden before any further work in a specific area. Removing too many stones at one time can lead to a total wall failure. In some cases, it may be necessary to anchor or temporarily brace the facade prior to stone replacement. Employ a qualified, experienced restoration contractor to perform the bracing, stone removal and replacement.

8. Partial Stone Replacement (Dutchman Repair)

8.1 For historic stone facades, partial stone replacement is often the preferred method for repairing stones that are generally in good condition, but have localized damage. With newer construction, the matching stone is more readily available and the decayed or damaged stone is usually easier to remove than that found on an older building. For these reasons, complete stone replacement is typically more viable with newer construction. Even so, partial stone replacement is sometimes the best alternative, even in newer buildings because of the possibility of damaging surrounding stone during removal of damaged stone.

8.2 Dutchman repairs involve cutting out damaged areas of a stone and replacing these areas with new pieces cut from matching stone bonded to the original with an adhesive. These can occur anywhere on a stone, yet are easier to address on the edge or corner of the stone unit. Typically, the area is cut out in a rectangular or square-like shape and the work can proceed relatively quickly. These repairs are usually not noticeable to